for which cable systems have capacity. Similarly, the number of broadcast stations in an average market divided into the downstream bandwidth available to the average subscriber will yield the "burden" on the cable industry of carriage of broadcast signals.

DTV Bandwidth "Burden"

Now looking at these relationships in detail, we have previously shown that the total bandwidth delivered to the average subscriber is growing from 622 MHz at yearend 1999 to 725 MHz at yearend 2003 according to the data supplied to the FCC by respondents to its survey. Subtracting the amount for upstream spectrum allocations, there is a net downstream capacity growing from 568 MHz to 671 MHz over the same period. (There is no need to subtract for limitations caused by technical or safety regulations, as there were none identified by any respondent.) Following the Commission's instructions to divide by three to determine the cap on bandwidth required to be devoted to commercial broadcast signals yields a value rising from 189.3 MHz at yearend 1999 to 223.7 MHz at yearend 2003.

Next considering the bandwidth required to carry broadcast signals, there are two types of signals to be considered – analog and digital – with two different bandwidths required. Analog (NTSC) signals occupy a 6 MHz channel for over-the-air broadcast, and they require the same bandwidth on a cable system. Thus there is a one-for-one correspondence between analog broadcast signals carried and the number of 6 MHz channels utilized for the purpose on a cable system.

Digital broadcast signals, on the other hand, use spectrum more efficiently and require less spectrum on a cable system than do analog signals. Because of the challenges of delivering digital signals reliably with tropospheric propagation, the 19.3 Mbps of a digital broadcast signal occupies the entirety of a 6 MHz channel for broadcast transmission. When that same signal is carried on a cable system, however, it occupies 71.5 percent of the capacity of a 6 MHz channel if 64-QAM modulation is used and half the capacity of a 6 MHz channel if 256-QAM modulation is used.

The cable industry respondents to the FCC survey indicated uniformly their expectations that two digital broadcast signals (or HDTV signals, in the language of the survey) will be carried on one 6 MHz channel using 256-QAM modulation. This is a reasonable expectation even for those operators with a large investment in set top boxes capable only of 64-QAM reception because the early set top boxes with that limitation are not capable of dealing with HDTV signals. Recovery and presentation of broadcast HDTV and other format signals will require new set top boxes or digital cable-ready receivers with that capability. Those subscribers desiring to receive such services will not be able to use the earlier generation set top boxes. Any new equipment placed in service will surely be capable of 256-QAM operation. Hence it is fair to assume that digital broadcast signals carried on cable systems will occupy half the capacity of a 256-QAM channel.

Another way to look at a digital broadcast signal occupying half a 256-QAM-modulated 6 MHz cable channel is to consider that it uses the equivalent of 3 MHz of cable spectrum. This leads to the ability to analyze broadcast channel occupancy on a cable system as consisting of two parts: an analog part requiring 6 MHz and a digital part requiring 3 MHz. When a station is afforded carriage of both its analog and digital signals, the two can be analyzed together as a single 9 MHz occupant of the cable system with respect to the downstream bandwidth utilized.

Capacity Within the One-Third Bandwidth Cap

Considering the bandwidth available for downstream transmission of commercial television broadcast signals within the one-third cap provided by the Communications Act of 1934 as amended[6] and the FCC's determination in the First Report and Order,[7] there was capacity available to the average subscriber to carry both the analog and digital signals of 21 stations at yearend 1999. (189.3 / 9) The capacity within that cap is projected by the cable industry survey to rise to nearly 25 stations at yearend 2003. (223.7 / 9) It should be noted that public ("Non-Commercial Educational" or NCE) stations are not counted in determining limitations to the Congressionally mandated cap.

Now consider the number of stations in the largest television markets in the country. Table 3 below lists the ten largest markets according to their Nielsen Designated Market Area (DMA) rankings, the total number of television stations in those DMAs, the number of commercial stations, and the number of public stations. The following analysis treats all the stations in each market as providing coverage throughout the DMA and therefore able to deliver a signal of sufficient quality to each cable headend to enable carriage on all cable systems in the DMA under the provisions of the FCC Rules.

Taken together, these data indicate that, for the average subscriber, there was capacity within the statutory cap to carry both the analog and digital signals of all the commercial broadcast television stations in the very largest markets by the end of 1999. By the end of 2003, there will be sufficient capacity within the cap to carry to the average subscriber both the analog and digital signals of all of the stations in the very largest markets, commercial and non-commercial alike. The capacity available to the average subscriber within the cap, moreover, is a conservative number. As shown earlier in Chart 5, fully 86 percent of subscribers are projected by the cable industry respondents to have 750 MHz or greater service by the end of 2003. The capacity projections here encompassing the number of stations in the largest markets are based on 725 MHz bandwidth service, leaving a 25 MHz (greater than 4-television-channel) margin.

Looked at another way, there were 1304 commercial television stations as of June 30, 2001, according to the FCC's data. Nielsen lists 210 DMAs. Thus the average DMA currently has about 6.2 commercial television stations. There were also 374 non-commercial educational (NCE) stations as of the same date, resulting in an average of about 1.8 such stations per DMA. If both the analog and digital signals of each commercial station in the average market were carried in the downstream bandwidth available to the average subscriber, the total "burden" on the cable industry currently would be 8.97 percent of that available downstream bandwidth.

[6] Section 614(b)(1)(B).

[7] First Report and Order and Further Notice of Proposed Rulemaking In the Matter of: Carriage of Digital Television Broadcast Signals, CS Docket 98-120, at Paragraph 40.

Table 3 — Television Stations in the Ten Largest DMAs

Rank	Market	Total TV	Commercial	NCE
1	New York	23	18	5
2	Los Angeles	25	21	4
3	Chicago	16	13	3
4	Philadelphia	20	15	5
5	San Francisco/Oakland/San Jose	23	18	5
6	Boston/Manchester, NH	20	15	5
7	Dallas	18	16	2
8	Washington, DC	18	12	6
9	Detroit	10	9	1
10	Atlanta	13	10	3

Source: Broadcasting & Cable Yearbook 2001

Historically, the percentage "burden" on the cable industry has fallen dramatically since the inception of must carry in 1993, as the capacity of cable systems has grown rapidly even while the number of television stations was also growing. In 1993, the burden of commercial television stations on the cable industry was 13.35 percent.[8] By yearend 1999, it had fallen to 6.25 percent – less than half the 1993 level – according to the cable industry respondents' capacity data combined with FCC data on the number of television stations.

During the period from yearend 1999 to yearend 2003, the burden of carrying both the analog and digital signals of all commercial television stations can be expected to grow as DTV stations are built. To model that growth, we have applied a factor to the effective bandwidth per station so that it grows from 6 MHz at yearend 1999 to 9 MHz at yearend 2002, when all commercial DTV stations are scheduled to be on the air.[9] This causes the burden to grow to a maximum of 8.46 percent at yearend 2002, after which it begins gradually to decline again as cable capacity continues to expand. This reduction occurs even after accounting for the fact that the total number of broadcast stations to be accommodated increases from 1243 on September 30, 1999, to an estimated 1320 on September 30, 2003. Beyond 2003, the burden can be expected to fall into the range of 7.9 percent as cable operators complete the capacity expansions they have described in their survey responses and elsewhere. Sometime further in the future, perhaps in "2010," the conditions will be met to allow discontinuance of NTSC operations. At that point and thereafter, the burden on the cable industry will drop to an average of 3 MHz per station, or 2.63 percent of bandwidth capacity delivered to the average subscriber.

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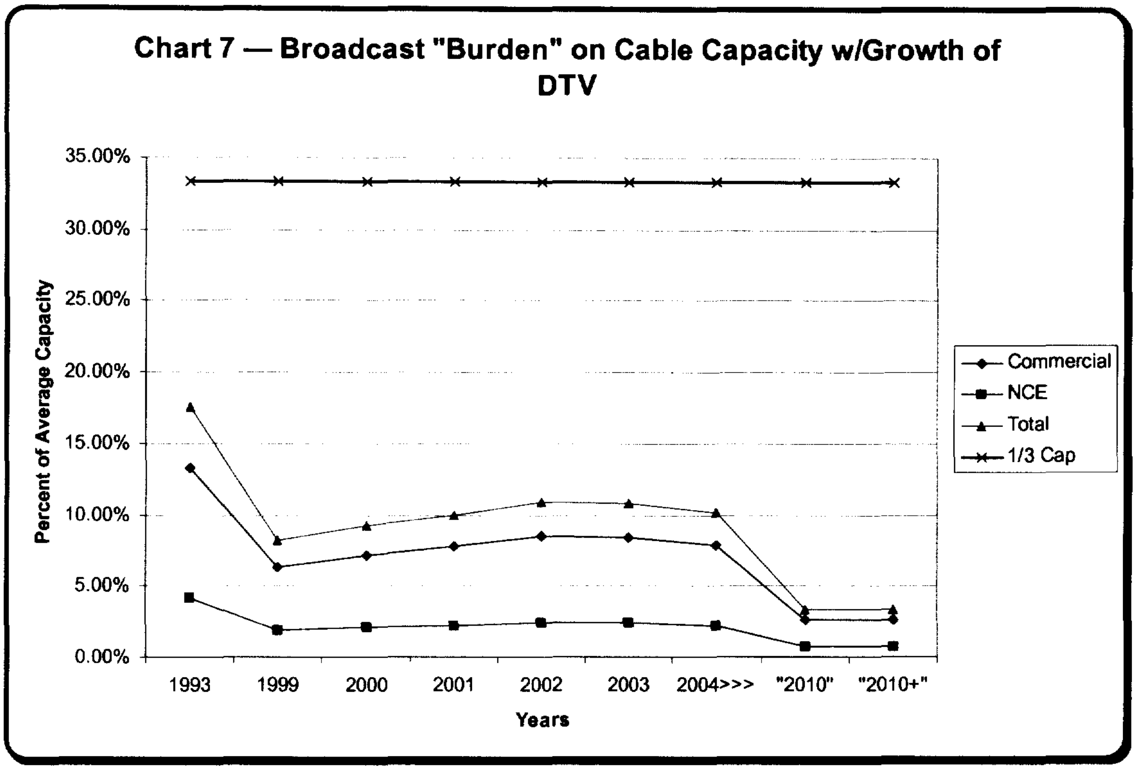
[8] Based on a total of 1,155 commercial television stations in 211 Nielsen DMAs and an average cable system capacity of 41 channels. Data are from the FCC, Nielsen, and Paul Kagan Associates, respectively.

[9] For sake of simplicity, the growth is modeled as a linear interpolation between 6 MHz and 9 MHz.



Accounting for the NCE stations as well, even though they are accommodated outside the one-third cap, the total "broadcast burden" on the cable industry declined from 17.55 percent in 1993 to 8.13 percent at yearend 1999. Using the same sort of model for growth of NCE digital operations but extending them from 2000 through 2003, the total broadcast burden climbs to 10.87 percent at yearend 2002, after which it begins falling. In the period beyond 2003, it is in the range of 10.1 percent until the analog signals are turned off. Thereafter the total burden on the cable industry will drop to 3.37 percent of bandwidth capacity delivered to the average subscriber, again assuming an average of 3 MHz per station. All of these relationships are shown in Chart 7.

Subscriber Representation in Survey Responses

All of these data are derived from the responses to the FCC survey combined with data from the FCC web site. The FCC survey responses cover a maximum of 57.3 million subscribers at yearend 2000 out of a universe of 68 million subscribers. In later years, because of discounting subscribers from respondents who supplied no data for those years, the total covered drops to 52.6 million out of an expected 68 million. The companies represented in the survey responses in any way have nearly 59.9 million subscribers out of the 68 million total subscriber universe, however, according to the data available from the NCTA web site. Thus the number of subscribers represented in the surveys overall is about 88.1 percent of the total. This is a very good representation for a survey such as this, but responses in the later years represent only 77.4 percent of all cable subscribers.

It could be argued that the remaining 22.6 percent of subscribers all subscribe to small systems, which would mean they receive lesser service than do their big-system brethren. Such an inference cannot be drawn, however, when one considers two factors: First, some 6.7 million, or 9.9 percent, of the missing subscribers are those of two respondents to the survey who failed to provide data for later years, the smaller of whose subscriber count is over 1 million. Second, the responses of the smaller operators who did return the survey indicate otherwise. Armstrong, BellSouth, and RCN, having 206,500, 39,700, and 413,400 subscribers projected in 2003, respectively, are among the leaders in bandwidth provided. They anticipate making available 750 MHz or greater bandwidth to 99.2, 100, and 86 percent of their subscribers, respectively. Thus it cannot be assumed that smaller operators, if indeed smaller operators were the ones missing from the data collected, would necessarily be below the average of the industry in the bandwidth delivered. It is therefore most appropriate to extrapolate from the data obtained on 77+ percent to the other almost 23 percent.

Because of some recent advances in technology, the bandwidth projections calculated above are likely to be conservative. The advances are the extension of the bandwidth of infrastructure equipment (amplifiers and the like) from 750 MHz to 860 or 870 MHz at no increase in capital cost to the operator. Moreover, such wider bandwidth equipment can be installed with the same amplifier spacing as has been used for 750 MHz, thereby avoiding the need to reposition the amplifiers along the cable in going to the higher bandwidth. These advances are described in detail in the brochure from Scientific Atlanta attached in Annex B. The impact of these advances is borne out by the upgrades installed by Adelphia, which is reported in the trade press to have used 750 MHz equipment in systems rebuilt after January 1, 1999, and to have used 860 MHz equipment exclusively in its rebuilds after February 1, 2000.[10] The expansion of the infrastructure bandwidth will not be hampered by the set top boxes and other equipment already in the field because all of them from the beginning of their introduction have had tuners that reach 860 MHz.[11] This is not to suggest that it should be expected that the cable industry as a whole will be moving beyond 750 MHz anytime soon but rather to underscore the conservative nature of the evaluation discussed above.

[10] It should be noted that, while Adelphia provided no data for year-ends beyond 2000 and was thus excluded from the averages for those years, it had 31.5 percent of its systems rebuilt at 750 MHz and 3 percent rebuilt at 860 MHz as of yearend 2000. This means that, as it rebuilds the remaining 65.5 percent of its systems, they will all be upgraded to 860 MHz. If these systems had been added to the averages calculated in this analysis, the bandwidth delivered to the average subscriber and the percentage of subscribers receiving service at or above 750 MHz both would have increased. This further confirms the conservative nature of the findings herein.

[11] The cable industry standard for digital modulation, SCTE DVS-031, "Digital Video Transmission Standard for Cable Television," has specified a transmission band from 54 to 860 MHz since its first release, dated October 15, 1996. The standard for devices connected to cable networks, SCTE DVS-313, "Digital Cable Network Interface Standard," first released March 15, 2000, specifies use of channel plans that extends to 864 MHz.

Cable Industry Program Service Capacity

Another way to look at the capacity of the cable industry is to consider the number of program services, popularly called "channels" but not necessarily related to the 6 MHz spectrum allocations also known by that term, that can be offered on a system. With regard to analog signals and program services, there is normally a one-to-one correspondence between them. For digital signals, the number of program services that can be carried on a single signal in a 6 MHz channel varies depending upon the type of program service to be carried and the quality of the service to be delivered to the subscriber's television screen. Digital signals are "compressed" to fit more into the available spectrum, and they are "multiplexed" so as to carry several of them together in a single 6 MHz channel.

The number of program services that can be multiplexed into a signal in a single 6 MHz channel depends upon the type of modulation used and the amount of compression to which the various services are subjected. The modulation type used determines the bit rate for the entire channel, and the compression determines the number of bits required to carry each program service. The number of bits devoted to each program service can also vary according to the complexity of the images to be compressed, and, when this is the case, efficiency of the system can be improved using a technique called "statistical multiplexing." It should also be noted that the bit rate required for a given image quality is smaller for film source material than it is for television sources. This situation occurs because film operates at a lower frame rate (24 Hz vs. 30 Hz) and because film images are taken at one instant while video generally is split into two fields taken at separate times. This factor allows the compression of more program services carrying films into a single channel than is possible with television-originated programming by a ratio of greater than 5:4.

Relationship Between Modulation and Compression Parameters

Some examples may help to explain the relationship between modulation and compression. First, we must remember that 64-QAM modulation is capable of transporting about 27 Megabits per second (Mbps), and 256-QAM can transport about 38 Mbps in a 6 MHz channel. If we were to combine 10 program services onto a channel with 64-QAM modulation, then each program service would have to be compressed to about 2.7 Mbps if we gave each service the same bit rate. If we used statistical multiplexing in this example, we could devote an average of 2.7 Mbps to each program service and get better image quality. Alternatively, we could retain the same image quality and reduce the average bit rate, perhaps allowing the multiplexing of an 11^{th} program service onto the channel. If we put the same services on a channel with 256-QAM modulation and we retained a fixed 2.7 Mbps bit rate, we could add another four program services for a total of 14. Use of statistical multiplexing would allow carriage of 14 services with improved image quality or retention of the same image quality with 15 or 16 program services carried.

Cable System Spectrum Allocation

Another factor to consider in calculating the number of program services that a cable system can carry is the allocation of spectrum to analog and to digital signals. Spectrum used for analog signals must be figured as carrying one program service per 6 MHz channel. Spectrum used for digital signals will carry multiple program services, with the multiplier a parameter that must be determined. The industry norm is to allocate spectrum below 550 MHz to analog services and to use the band above 550 MHz for digital services. Some operators deviate from that norm, however, in some cases allocating some of the spectrum above 550 MHz to analog services and in other cases digitizing some analog services below 550 MHz to make room in that part of the spectrum for some digital signals that can carry more services.

One more factor that must be included in calculation of the number of program services likely in real implementations is the amount of spectrum that will be allocated for the downstream portions of two-way services such as telephony and Internet connectivity using cable modems. The amount required depends upon the architecture of the cable system. With practically all cable operators having adopted the hybrid fiber-coax (HFC) design, the bandwidth required for these services is that needed to serve the needs of the number of subscribers attached to each node of the system. The node is the point at which the signals transition from a fiber from the headend to a coaxial cable to the subscribers' premises. As more subscribers adopt a particular service, more bandwidth is required in order to serve them. Typically, that additional bandwidth is created by splitting nodes so that they serve fewer subscribers. This permits "frequency reuse," which makes more efficient use of the spectrum on the coaxial cable by using more fibers to connect the nodes to the headend. Such frequency reuse is more or less required because there is not sufficient bandwidth in the upstream spectrum to be able to simply expand the bandwidth allocated to the two-way services.

Number of Program Services Per Digital Channel

In the analysis to follow, the cable industry capacity will be considered in terms of the number of program services that can be carried. To simplify the discussion, only the values for yearend 2003 will be described in detail. The same methods have been applied, however, to the proceeding years, i.e., starting at yearend 1999. The results of that complete analysis are given graphically in Charts 8 and 9, respectively, for the unweighted and weighted average numbers of program services per channel derived from the cable operators' data, as will be described below.

The FCC survey asked the cable operators for the number of High Definition Television (HDTV) and Standard Definition Television (SDTV) program streams expected per 6 MHz channel. The responses for HDTV were discussed above. For SDTV, the responses naturally vary from operator-to-operator, but there are visible trends in the data. The data are presented in summary form in Table 4 below. The data entries indicate the number of program services each responding operator projected that it will multiplex into a single 6 MHz channel using 64-QAM and 256-QAM modulation. "NR" indicates no response from a particular operator with respect to a specific density of modulation. In some cases, there were no responses at all from an operator. In other cases, only one form of modulation was considered. In the case of one operator, there was no differentiation made between the two forms of modulation. One operator provided independent answers from three different administrative regions that dealt with different aspects of the issues and did not necessarily agree with one another.

Table 4 — Cable Operator Estimates of Number of Services per Channel

Respondent	64-QAM	256-QAM
Adelphia	NR / 8-12 / 8*	8 / NR / NR*
Armstrong	8	NR
AT&T	10	12-14
BellSouth	6-12	NR
CableOne	NR	NR
Cablevision	7	10
Charter	8	8-11
Comcast	8	12
Cox	N/R	NR
Insight	8-12	NR
RCN	NR	NR
TWC	6-12**	6-12**

* Responses given independently by three regions
** No differentiation between 64-QAM & 256-QAM
NR No response

To further analyze the data, where a single value was given, it was used without modification to represent all cases, i.e., both film and video sources. It was also assumed to recognize the added efficiencies of statistical multiplexing. Where a range of values was given, the average of the range was used to represent the response from that operator for the particular modulation density. Where a single operator gave multiple responses, the average of the ranges and values was used. The data were then combined in two ways. First the average of the responses from all operators providing information was determined for each modulation density. Second, the response from each operator providing information for each modulation density was weighted by the number of its subscribers and the average then determined among the number of subscribers for whom data was available for that modulation density.

The results of this data analysis are that the unweighted averages of the responses from all operators responding about each modulation density are 8.67 program services for each 64-QAM channel and 10.25 program services for each 256-QAM channel. The ratio between the 256-QAM and the 64-QAM averages is about 1.18-to-1. This shows that either the cable operators do not fully acknowledge the 40+ percent increase in bit rate bandwidth that comes from use of 256-QAM vs. 64-QAM or they intend to use the additional bit rate to increase image quality. The corresponding weighted averages for 64-QAM and 256-QAM, respectively, are 8.92 and 10.70 program services. Again, the ratio between the 256-QAM and the 64-QAM weighted averages is about 1.20-to-1, showing less than full recognition of the bit rate bandwidth difference between the two modulation densities.

While it would be very simple blithely to assume that the bit rate of 256-QAM could be used for all cable services, this would fail to recognize that there are costs associated with a conversion from 64-QAM to 256-QAM. As previously discussed, some cable operators have costs sunk in set top boxes with capability only for 64-QAM. There also is the matter of the delivery of programs by satellite already multiplexed at bit rates appropriate for 64-QAM by services such as the Headend In The Sky (HITS) and by some of the programmers supplying their own multiplexes. In instances such as these, it is necessary to demultiplex (in a process called "grooming") the pre-multiplexed services in order to recombine them into larger groups for 256-QAM transmission. Such remultiplexing can be done today but is relatively expensive. Consequently, in this report, we have taken the conservative path of not making any assumptions about the operators' conversion to 256-QAM beyond using it as an upper bound on the range of what might be possible. It should be noted, however, that the impact of Moore's law, tracing the reduction in cost of semiconductor processing power, will be felt in this area, as future devices such as modulators are currently planned by some manufacturers to have remultiplexing capability built in. Such developments will make the conversion from 64-QAM to 256-QAM more economical in time.

Spectrum Allocation for Analog Video, HDTV, and Other Services

The FCC survey sought data on the amount of spectrum historically used and expected to be used in the future for analog video. In general, the responses show that 496 MHz will be used in systems of 550 MHz bandwidth or greater. Considering that the spectrum below 54 MHz is reserved for upstream signals, this accounts for everything up to 550 MHz. There are some operators who will use spectrum from the region above 550 MHz for analog services, but there are just as many who will use spectrum below 550 MHz for digital services, even on systems with only 550 MHz total bandwidth. Therefore, in this analysis, the spectrum from 54 MHz up to 550 MHz will be treated as used for analog signals, and the spectrum above 550 MHz will be treated as used for digital signals.

The FCC survey also sought data on the amount of spectrum used and expected to be used for services other than video. The responses in this category were primarily related to telephony and data services to cable modems. Some operators also included a variety of potential new services in this category such as pay-per-view (PPV), video-on-demand (VOD), interactive television (ITV), audio-only services, and the like. Examination of these items shows that several of them (e.g., PPV, VOD) are video services nonetheless, while others such as the audio-only services are broadcast services in essence. The ones that are really of a different nature are the telephony services and the data services. Data from the cable operators on these services shows allocation of 1 or 2 channels of 6 MHz bandwidth to telephony and, with but one exception, 2 channels of 6 MHz bandwidth to data transmission. For purposes of this analysis, a total of 4 channels, or 24 MHz, will be considered allocated to the downstream portions of these two-way applications. This means that the other newer applications like PPV and VOD will be handled within the spectrum allocated for downstream delivery of digital video signals. It should be noted that some of these newer applications, VOD in particular, will benefit from, perhaps require, the frequency reuse that comes from node splitting as described previously. This result comes from the necessity to send different signals to each user, just as in the case of data delivery.

A further factor to consider in arriving at the program service capacity of the cable industry is the amount of HDTV programming that will be carried. The reason that this must be broken out separately is that it requires more bits and hence more bandwidth than is needed to carry SDTV content. HDTV programming can come from two primary sources: broadcast signals and cable networks. As discussed previously, there is general consensus among cable operators that two broadcast signals (which, of course, really can be either HDTV or multiple SDTV signals) can be carried in a single 6 MHz channel, with an assumption of use of 256-QAM modulation to achieve this. The respondents to the FCC survey presented two different possibilities in regard to HDTV service from cable networks. Some noted that cable HDTV often uses a lower bit rate (resulting from starting with a lower horizontal resolution) than that of broadcast HDTV, and thus it may be possible to fit three cable HDTV services into a single 6 MHz channel rather than two. The others treated cable HDTV the same as broadcast HDTV, i.e., two per channel. For purposes of this analysis, so as to be conservative in counting the number of program services that can be provided, two services will be counted per 6 MHz channel devoted to cable HDTV.

It remains to determine the number of HDTV services to be included in the total. Since this analysis is dealing with national averages, the number of digital broadcast (DTV) stations included will be the average number per market, i.e., 6.2. This means that 3.1 channels will be set aside for broadcast DTV carriage and will be counted as carrying 6.2 program services. As to cable HDTV, the same number of program services will be considered as originating from cable sources as from broadcast. This will result in another 3.1 channels being treated as carrying HDTV, and they will be counted as yielding another 6.2 program services. Thus, altogether, 6.2 channels, yielding 12.4 program services, will be set aside for DTV/HDTV.

Calculations of Cable Industry Program Service Capacity

With all of these individual elements now determined, the average cable industry capacity in terms of number of program services can be calculated. Starting from the total bandwidth delivered to the average subscriber at yearend 2003, i.e., 725.2 MHz, it is necessary to subtract the upstream spectrum of 54 MHz. Then the 496 MHz used for analog services and the 24 MHz used for the downstream portions of two-way services are subtracted, leaving 151.2 MHz above the 550 MHz transition point between analog and digital services. The 496 MHz is counted as 80 analog program services, the value normally quoted by the cable industry, even though it actually represents 82.7 channels of

6 MHz each. The 24 MHz allocation is not counted toward the number of program services. Next the 151.2 MHz remaining above the 550 MHz transition point is divided into 6 MHz channels, resulting in 25.2 of them. Of these, 6.2 are set aside for broadcast and cable DTV/HDTV services, leaving 19 channels for the variety of SDTV, PPV, VOD, and similar services. The 6.2 channels for DTV/HDTV are counted as 12.4 program services. So far, this accounts for 92.4 program services delivered to the average subscriber.

The remaining 19 channels are analyzed in four different ways to give a complete picture of cable industry program service capacity under different scenarios. Start with the cable operators' values for the number of program services per channel with 64-QAM and with 256-QAM modulation. Consider both the unweighted average of cable operator responses and the average weighted by number of subscribers per operator as discussed previously. Multiplying the 19 channels by the unweighted and weighted average number of program services for both modulation densities results in four values. These values are 164.7 program services for 64-QAM and 194.7 program services for 256-QAM, unweighted, and 169.4 program services for 64-QAM and 203.3 program services for 256-QAM, weighted.

The numbers of program services obtained in the four cases for the 19 channels must be added to the 92.4 program services representing the analog services combined with the DTV/HDTV services. The results are 257.1 total program services when 64-QAM is used and 287.1 total program services when 256-QAM is used and the number of program services per channel is the unweighted average of the cable operators' responses. Similarly, the total number of program services is 261.8 with 64-QAM and 295.7 with 256-QAM when the cable operators' responses are weighted by the numbers of their subscribers.

Since it is unlikely that any particular cable system will use exclusively 64-QAM or 256-QAM during the period under consideration, the numbers of program services for each modulation density can be considered the ends of a range of likely values. This allows simplification to a range of 257.1 to 287.1 program services, unweighted, and a range of 261.8 to 295.7 program services, weighted by number of subscribers, at yearend 2003. The equivalent ranges for the other years in the survey exist between the lines in Chart 8 for the unweighted case and Chart 9 for the weighted case.

It should be noted that, while the cable operators' values have been used exclusively up to this point for the number of program services to be carried on 64-QAM and 256-QAM, other results are possible. For example, suppose the cable operators' values were used for 64-QAM and the values for 256-QAM were set 40 percent higher, as would be expected from just the difference in bit rates. The ranges would become 257.1 to 322.9 program services, unweighted, and 261.8 to 329.6 program services, weighted by the number of subscribers. These kinds of improvements in capacity can be expected going forward as a result of improvements coming in compression and multiplexing technology and the lower bit rates required for the preponderance of film-originated material that will be carried on PPV and VOD services.

Chart 8 — Total Program Services — Unweighted Averages

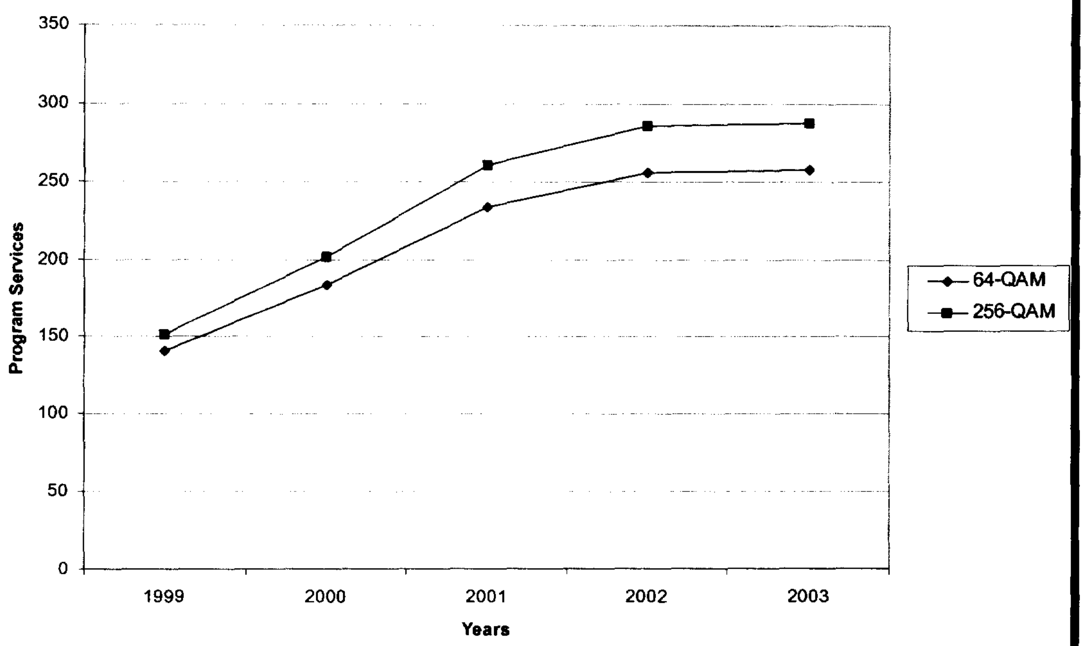
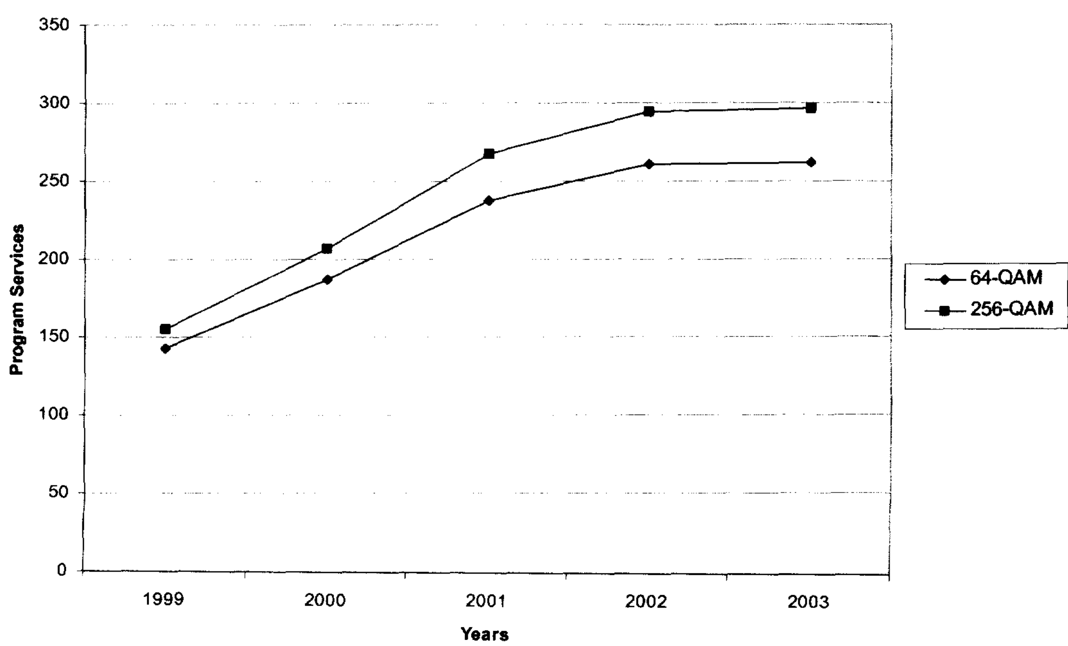


Chart 9 — Total Program Services — Weighted Averages



Since 86 percent of subscribers are projected to have 750 MHz or greater total bandwidth service by the end of the survey period, yearend 2003, it is instructive to evaluate the number of program services that they could receive. Replacing the total bandwidth received by the average subscriber with the value 750 MHz in the process described above yields 23.13 channels, after subtracting for analog channels, downstream portions of two-way services, and DTV/HDTV services. (The value 23.13 equates to the 19 channels of the previous analysis. Thus the 86 percent of subscribers will receive 4.13 more 6 MHz channels than the average subscriber receives.) The program service capacity of the 23.13 channels must be evaluated for the four cases of unweighted and weighted numbers of program services per channel (as derived from the cable operators' responses) when 64-QAM and 256-QAM modulation are used. The resulting numbers of program services must be added to the 92.4 program services that are carried on the analog channels plus the DTV/HDTV channels as previously described. This produces ranges of 292.9 to 329.5 program services, unweighted, and 298.7 to 339.9 program services, weighted by numbers of subscribers, that will be delivered to those 86 percent of subscribers who will receive 750 MHz or greater total bandwidth service. Looked at another way, 86 percent of subscribers will receive between 36.9 and 44.2 more program services than will the average subscriber who has formed the basis for this examination (with the analysis done using the cable operators' values for program services per channel weighted by numbers of subscribers).

Conclusions

The data from the responses of a dozen mostly large and some smaller cable operators to the FCC survey on cable system capacity have been analyzed. The number of subscribers represented by the companies responding totals 59.9 million out of the current universe of 68 million cable subscribers. Data for systems serving up to 57.3 million subscribers is included in the survey responses, with 52.6 million covered in the last two years of the period considered. Thus 77.4 percent of cable subscribers are directly represented in those last two years. It has been shown that the information available for the 77+ percent of subscribers can be conservatively applied to the remaining 22.6 percent.

At this point, a number of characteristics of cable system capacity, as revealed by the data supplied by cable operators, should be apparent. They can be summarized with respect to bandwidth capacity, broadcast DTV "burden," and program service capacity. They are presented here in summary form:

Cable Industry Bandwidth Capacity

- Overall bandwidth delivered to the average subscriber increases from 622 MHz to 725.2 MHz over the period from yearend 1999 to yearend 2003.

- Downstream bandwidth to the average subscriber increases from 568 MHz to 671.2 MHz over the period.

- Subscribers receiving 750 MHz or greater total bandwidth service increase from 56.1 to 86 percent over the period.

- Subscribers receiving greater than 750 MHz service (typically 860 or 870 MHz service) increase from 0.9 percent to 11.8 percent over the period.
- Subscribers receiving 550 MHz service or less decline from 43.8 percent to 14 percent over the period.
- Following the survey period, bandwidth delivered to the average subscriber will continue to increase through completion of the upgrades currently known to be under way, at which point downstream bandwidth is projected to reach 717.6 MHz.

Cable Industry "Burden" from Carriage of Broadcast DTV Signals

- For purposes of analysis, the average of about 6.2 commercial television stations per market was used in the calculations.
- For purposes of analysis, the average of about 1.8 non-commercial educational (NCE) television stations per market was used in the calculations.
- The downstream bandwidth to the average subscriber over the entire period is sufficient to carry all the commercial television stations in the very largest markets in both analog and digital form within the one-third bandwidth cap determined by the FCC to meet the requirements of the Communications Act of 1934 as amended.
- The downstream bandwidth to the average subscriber by the end of the period is sufficient to carry all the commercial and non-commercial television stations in the very largest markets in both analog and digital form within the one-third bandwidth statutory cap as determined of the FCC.
- The "burden" on downstream bandwidth to the average subscriber to carry both the analog and digital signals of the commercial television stations in the average television market grows from 6.25 to 8.43 percent over the period covered by the survey.
- The "burden" on downstream bandwidth to the average subscriber to carry both the analog and digital signals of both the commercial and non-commercial television stations in the average television market grows from 8.13 to 10.82 percent over the period covered by the survey, recognizing that NCE stations are not counted in the one-third cap.
- Following the survey period, the "burden" on downstream bandwidth to the average subscriber to carry both the analog and digital signals of the commercial television stations in the average television market declines to 7.88 percent as the upgrades currently known to be under way reach completion.
- Over the period from 1993 to the end of the DTV transition, the "burden" on downstream bandwidth to the average subscriber for carriage of the signals of commercial television stations declines from 13.35 percent to 2.63 percent.

Cable Industry Program Service Capacity

- Cable operators confirmed the use of the lower 54 MHz of systems for upstream signals.
- Cable operators indicated 550 MHz is the upper limit for analog downstream signals, with some deviations from that value.
- Cable operators indicated that spectrum above 550 MHz will be used for digital downstream signals, with some deviations from that value.
- Cable operators indicated that 24 MHz is needed, in general, for the downstream portions of two-way services.
- Cable operators were unanimous that 2 DTV signals can be carried in a single 6 MHz channel using 256-QAM modulation.
- Cable operators indicated that 2 or 3 cable HDTV services can be carried in a single 6 MHz channel using 256-QAM modulation.
- Cable operators indicated that use of 256-QAM modulation in their digital allocations of their spectrum is feasible by their inclusion of it in their plans.
- Cable operators, on average, expect 8.67 SDTV program services to be carried in a single 6 MHz channel using 64-QAM modulation.
- Cable operators, on average, expect 10.25 SDTV program services to be carried in a single 6 MHz channel using 256-QAM modulation.
- Cable operators, after weighting by the numbers of their subscribers, expect 8.92 SDTV program services to be carried in a single 6 MHz channel using 64-QAM modulation.
- Cable operators, after weighting by the numbers of their subscribers, expect 10.70 SDTV program services to be carried in a single 6 MHz channel using 256-QAM modulation.
- After accounting for all other factors, calculations show a capacity range of 257.1 to 287.1 total program services to the average subscriber, when cable operators' expectations for program services per channel are treated on an unweighted basis.
- After accounting for all other factors, calculations show a capacity range of 261.8 to 295.7 total program services to the average subscriber, when cable operators' expectations for program services per channel are weighted by the numbers of their subscribers.

- After accounting for all other factors, calculations show a capacity range of 257.1 to 322.9 total program services to the average subscriber, when cable operators' expectations for program services per channel are treated on an unweighted basis for 64-QAM and when 256-QAM capacity is taken as 40 percent higher by virtue of bit rate capacity.

- After accounting for all other factors, calculations show a capacity range of 261.8 to 329.6 total program services to the average subscriber, when cable operators' expectations for program services per channel are weighted by the numbers of their subscribers for 64-QAM and when 256-QAM capacity is taken as 40 percent higher by virtue of bit rate capacity.

- After accounting for all other factors, calculations show a capacity range of 292.9 to 329.5 total program services to the 86 percent of subscribers receiving 750 MHz or more total bandwidth service at the end of the period, when cable operators' expectations for program services per channel are treated on an unweighted basis.

- After accounting for all other factors, calculations show a capacity range of 298.7 to 339.9 total program services to the 86 percent of subscribers receiving 750 MHz or more total bandwidth service at the end of the period, when cable operators' expectations for program services per channel are weighted by the numbers of their subscribers.

- Over the period covered by the survey, the cable industry will increase program service capacity by 83.5 percent, considering 64-QAM modulation alone. The real increase is certain to be higher than this when it is recognized that most operators indicated an intention to use 256-QAM for parts of their SDTV services.

Annex A — Treatment of Cable Operators' Data

Some explanations of the methods used to arrive at the various values shown in the several charts are required. The treatment of each operator's data will be discussed in succession. A variety of steps were sometimes required to make the data consistent from one operator to another and to make it relevant to the question. The need for this treatment results from the fact that some operators did not provide the data requested but instead substituted other, somewhat related data they had at hand. In other instances, only partial data was supplied, and it has been necessary to extend some data provided or to fill in certain details in order to make what was supplied relevant to the question. These instances will be described in detail in the next several paragraphs about the data supplied by the respective operators, taken in alphabetic order.

Adelphia Communications supplied data only for yearend 1999 and 2000. It supplied no projections of future upgrades. It supplied subscriber numbers and route miles of the various bandwidths organized by state. For both years it supplied subscriber numbers for 28 states. It supplied bandwidth data for 11 states for 1999 and for 29 states for 2000. For both years there were states with bandwidth data and no population data, even with the relatively large disparity in favor of population data in 1999. Obviously in that year, there were many states for which population data were supplied but no bandwidth data. In order to make the data useful, it was treated in the aggregate, i.e., the total population was used and the total route mileage for each bandwidth was used to arrive at a percentage of the total plant to ascribe to that bandwidth category. It was assumed that the population was uniformly distributed in the systems and along the routes so that the proportion of each bandwidth in each year could be applied to the total subscriber base. It should be noted that the subscriber data supplied by Adelphia (3,876,468 at yearend 1999 and 4,317,865 at yearend 2000) is at considerable variance from the number of subscribers credited to Adelphia by the National Cable and Telecommunications Association (NCTA) on its web site (5,292,000 at yearend 2000).

Adelphia Communications is the only operator to supply data that indicates a year-to-year increase in plant percentage below 500 MHz. Similarly, its data show reductions in the percentages of both 550 MHz and 750 MHz service while there is a very slight uptick in the data for service above 750 MHz. This very likely may be due to the large amount of missing data for the year 1999 and the fact that no data were supplied beyond yearend 2000. Since there were no projections of proportions of the service categories for future years nor any indications of expected numbers of subscribers in those years and since there are such gross discrepancies in the subscriber data that were provided, the data for Adelphia are included in the aggregation for the industry only in the years for which the data were supplied. This results in undercounting the subscribers covered by the survey in those years, but, given the relatively small number of subscribers involved (about 5 million out of nearly 57 million), it does not significantly impact the portrayal of overall industry trends and averages.

Armstrong Cable Services supplied bandwidth data for all years in the survey. It likewise supplied numbers of subscribers receiving service in each bandwidth category. It used a constant number for the total of subscribers in all years, thereby not reflecting its history or expectations of future changes in the number of subscribers. Given that its total number of subscribers is small (about 206,500), this has no significant impact on the results obtained.

AT&T Broadband supplied complete information for the year-ends 2000 through 2003. It excluded yearend 1999 statistics because they would not have contained MediaOne data and were therefore seen as "distort[ing] the aggregate year-to-year comparison of rebuild activity." The AT&T data were based upon plant bandwidths projected on a Homes Passed basis and were supplied already converted to number of subscribers based upon an assumed even distribution of subscribers. The respondent indicated that it does not separately maintain data for 750 MHz and greater-than-750 MHz systems, so it has reported the two together. In our analysis, the AT&T data for greater-than-or-equal-to 750 MHz were included with the data from other operators in the 750 MHz category. This has the effect of under-reporting the >750 MHz data and over-reporting the 750 MHz data to the extent that AT&T has any systems operating at over 750 MHz at any time.

BellSouth Interactive Media Services supplied data for all years requested. 100 percent of its systems operate at 750 MHz. It has only on the order of 40,000 subscribers, so its impact on the industry aggregate is small in any event.

CableOne supplied all requested data for Question 1. No adjustments therefore were required. It is worthy to note that all data for yearend 2001 were precisely repeated in table entries for the following two years. The bulk of CableOne subscribers will receive 550 MHz service throughout the period covered by the table, with nearly 55 percent receiving such service over the last three years on the table. Its subscriber totals are relatively small, however, with only 770,000 shown in the last three years.

Cablevision Systems supplied its information on percentages of Homes Passed that would receive the various categories of service if subscribers occupied those homes. To make the data comparable to that supplied by other system operators, it was adjusted by the fraction 3 / 4.2 that represents the number of Cablevision's subscribers divided by the number of homes its systems pass. These values were provided in the cover letter that accompanied Cablevision's response to the survey as representative of the current situation.

Charter Communications provided all the requested information and projects the second largest proportion of service at greater than 750 MHz, with over 46 percent of subscribers receiving such service by the end of 2003. It was one of only two operators to indicate any system capacity in the range from 550 to 750 MHz. Subscribers expected to receive that bandwidth never exceed 0.8 percent, so the range value has been combined with the 550 MHz value to be more meaningful. It should be noted that Charter supplied only one value for the number of its subscribers for all five years.

Comcast provided information for the first four years in the requested range (through 2002). So as not to lose the effect of over 8 million subscribers in the last year, we have repeated the data from yearend 2002 in the 2003 column as well. It should be noted that

Comcast did not provide separate information in the table on the extent of its system construction at 860 MHz, although it did note that it was including that data together with the 750 MHz data included in the survey. It indicates in its notes to the table that it is upgrading 20 communities in eleven states to 860 MHz bandwidth. Similarly, Comcast included any systems between 550 and 750 MHz with the 550 MHz data. Given that the trend shown for 750 MHz is strongly up, that the trends both for under 500 MHz and for 550 MHz are strongly down, and that the data for 860 MHz are included with the 750 MHz data, it can be stated that the Comcast data understates the 860 MHz numbers and simultaneously overstates the 750 MHz numbers – probably to a significant degree.

Cox Communications supplied only the information about the proportion of its systems falling into the several categories of bandwidth historically and its expectations for those percentages in the future. It did not supply any data on the number of its subscribers in each category or in toto. So as to make the Cox data comparable to that from the other system operators, the needed information on its number of subscribers as of December 2000, was obtained from the NCTA web site and used in the table. In the absence of more detailed information from Cox, the same number of subscribers was applied to all years under consideration, as had been done by several of the other operators in their responses.

Insight Communications provided only historical data for the year-ends of 1999 and 2000. It provided no projections of the proportions of its subscribers it expects to receive service at the several categorical levels defined in the survey. Consequently its data appears in only the first two years of the charts showing the proportions of subscribers served at each bandwidth level by each operator (Charts 1 through 4). Its data also contribute only to the aggregate presentations (in Charts 5 and 6) for those same two years.

Insight described the amount of plant it has with bandwidth greater than 750 MHz as "immaterial, and therefore not 'representative.'" Nevertheless, the total of the categorical information supplied by Insight adds to less than 100 percent, and the yearly subscriber total does not match the total of subscribers in all categories given for each year. Since Insight made it clear that the missing subscribers receive greater than 750 MHz service, we have calculated the number of missing subscribers and the percentages they represent and inserted them into the >750 MHz category. (For reference, the percentages are 1.5 percent in 1999 and 3.8 percent in 2000.)

RCN Corporation provided information on the proportions of its subscribers who received service in the different bandwidth categories but gave no information whatsoever on the number of its subscribers. The needed information on RCN's number of subscribers as of December 2000, was therefore obtained from the NCTA web site and used in the table. Since only a single value was available for the subscriber number, it was used for all years, as had been done by several of the other respondents to the survey in the data they supplied. It is worthy to note that RCN projects the highest proportion of service (58 percent by yearend 2003) at >750 MHz of any of the operators responding to the survey.

Time Warner Cable (TWC) did not fill in any of the tables from the survey. Instead it provided a completely narrative answer to the questions posed. Notwithstanding the difference in form, TWC did provide a substantial amount of useful information (but not all that was requested by the survey). With the information that was supplied, we were able to fill in the table to a large extent and then to combine the information with that from other operators to obtain the industry averages that we have presented.

TWC gave specific information on the proportion of subscribers who received historically or will receive in the future service below 500 MHz. These were indicated by TWC as dropping to zero in the next couple years. TWC also indicated the percentage of subscribers still served by 550 MHz systems (2 percent); we carried that number into future years as a conservative estimate. TWC said that it currently serves 94 percent of its subscribers with 750 MHz or greater bandwidth and that its New York City division operates at 860 MHz. The TV Factbook 2001 edition lists the TWC New York City systems (including Staten Island) as serving 1.254 million subscribers, so we applied that number in the >750 MHz category while subtracting it from 94 percent of the total to yield the number for the 750 MHz category. To make the transition to the information provided a reasonable one, we tapered the data for 550 MHz subscriber percentages by 2 percent per year (probably rather less than reality, but a conservative estimate) to the value given by TWC as representing the current situation. We then subtracted the total of the two bottom categories from 100 percent to obtain the percentage of subscribers in the two highest categories in any year. We split that number to account for the New York City division's wider bandwidth, ascribing half the change to yearend 2000 and half to yearend 2001.

New Interactive Services and Expanded Channel Lineups Make 870 MHz a Necessity

A White Paper By Scientific-Atlanta, Inc.

Bandwidth: Your Most Precious Resource

The one thing that cable operators can never have too much of is bandwidth. And, with deployment of new digital interactive services underway in many areas, bandwidth is becoming a more precious resource every day.

While the cable industry has embarked on a long term trend to increase capacity, most MSOs are still operating networks at or below 550 MHz. This provides capacity that is capable of supporting only 80 channels of broadcast analog, leaving no room for additional analog or digital channels. Nor does a 550 MHz system have much room to offer new services, such as video on demand, Internet access and IP telephony.

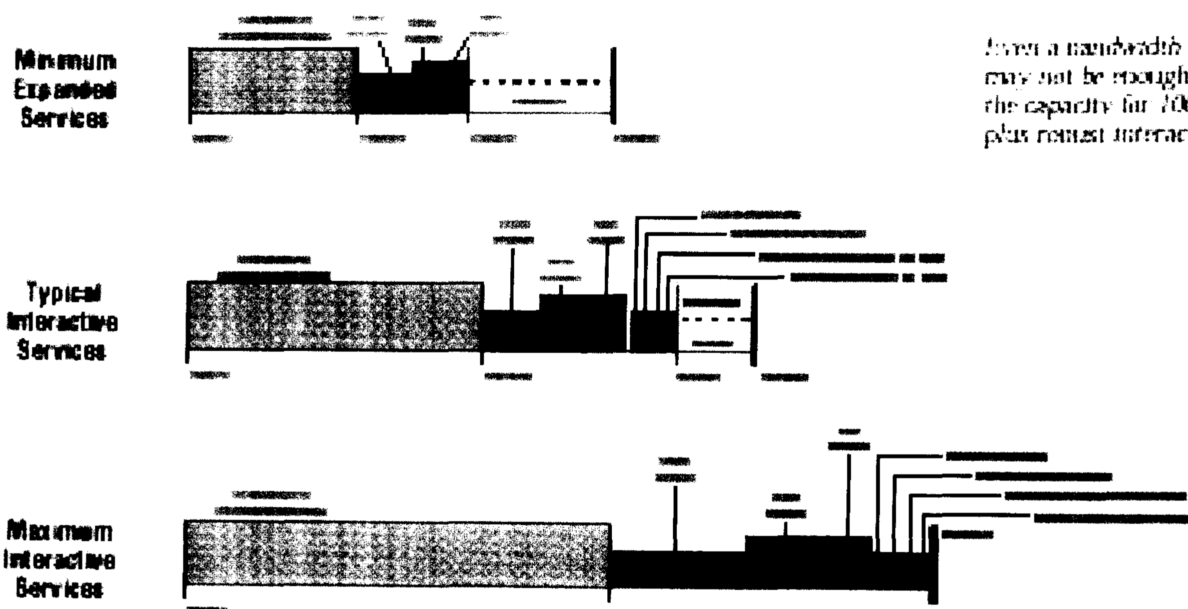
Some cable operators may not feel a pressing need to upgrade their bandwidth because they don't plan to significantly add to their service offerings in the near future. They may believe that upgrading to 750 MHz or even 870 MHz would be an unnecessary expense. However, history indicates that service demand is constantly overtaking bandwidth capacity. Almost every operator will soon need more than 550 MHz, especially with the emergence of digital broadcasts.

In addition, operators that maximize their bandwidth are sure to greatly increase the value of their companies. Recent acquisitions in the cable industry are strong votes of confidence in cable as the network of the future provided that cable operators continue their efforts to increase network capacity and offer more revenue generating services.

Rather than asking, "Should we upgrade to 750 MHz?" operators should really be asking, "Is 750 MHz enough?" In many areas — especially for operators in metropolitan areas where "must carry" rules limit the operator's choices of what channels to add — operators may need more than 100 channels to meet competitive threats. A bandwidth of 750 MHz simply can't provide that much channel capacity and still have spectrum available for interactive services.

The thesis of this paper is simple: For competitive reasons, most operators will need to upgrade beyond 550 MHz. And, now there's a compelling business case to go beyond 750 MHz to 870 MHz. No complex models are needed to cost justify the extra 120 Mhz, because the ***incremental cost is now zero!***

More Bandwidth = More Services



Even a bandwidth of 750 MHz may not be enough to provide the capacity for 100 channels, plus robust interactive services.

2

Smaller Nodes, More Fiber Aren't Complete Solutions

Some operators have attempted to postpone upgrades by breaking 2,000 home nodes into 500 home nodes, therefore increasing capacity to allow some additions to the network. But, as customer demands continue to grow and competition increases the pressure to add channels and services, upgrading bandwidth beyond 750 MHz becomes inevitable. Even without additions of new channels, more bandwidth will be needed for the migration from analog to digital. Also, in most cases, it is less expensive to add bandwidth to a network than it is to segment nodes.

Increased use of fiber optics doesn't solve the network capacity problem, either. While pushing fiber deeper into the network is helpful in improving network performance, more bandwidth will still be necessary for expansion of broadcast channels and introduction of interactive services.

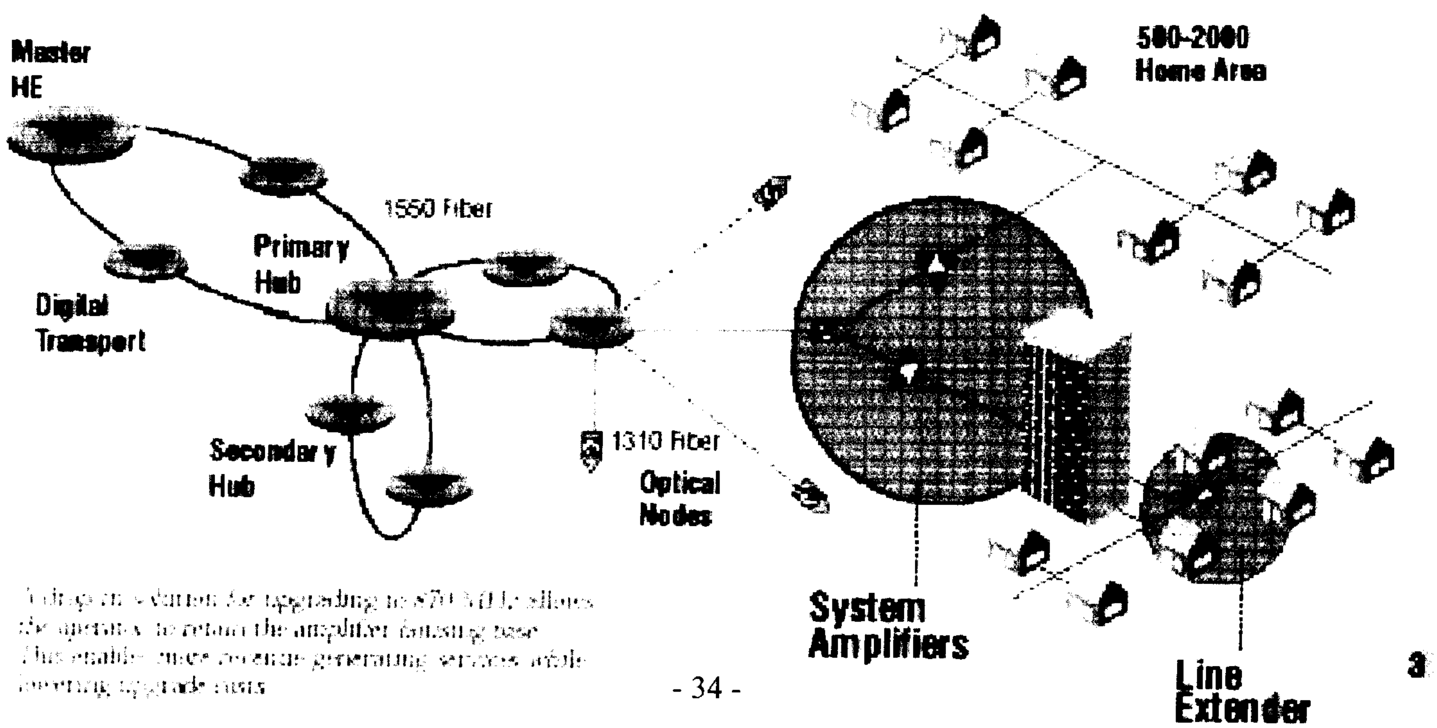
Upgrades Delayed – At What Cost?

The obvious reason for questioning any bandwidth increase is cost. While operators realize that new interactive services, expanded channel lineups and HDTV are inevitable, their plants are, at best, designed and spaced for 750 MHz. Not to mention the fact that just adding the new services can be a very expensive task in itself. So, the idea of rebuilding the plant can be a daunting one for operators.

However, the alternative is likely even more costly. By postponing or even eliminating plans to upgrade, operators risk losing customers to the competition. They also lose the opportunity to generate new revenue from services that they won't have the bandwidth to introduce.

Moreover, operators are allowed to raise their rates as they increase their video channels, so the expense to upgrade can be somewhat offset by rates. And, as the reverse path is activated, the value of even one MHz becomes huge for cable modem service. As a cable company executive once said, "Nobody ever got fired for having too much bandwidth."

System Amplifiers: Vital Links in the Network



A drop-in solution for upgrading to 870 MHz allows the operator to retain the amplifier housing base. This enables more revenue generating services while lowering upgrade costs.

Solution: 870 MHz For The Price Of 750 MHz

For operators committed to upgrading capacity, a new solution makes the 750 vs. 870 MHz decision a no brainer.

Scientific-Atlanta, Inc., a leading supplier of broadband communications systems, satellite-based video, voice and data communications networks, has introduced a new RF amplifier platform that enables an upgrade to 870 MHz for the same cost of 750 MHz. That's an extra 120 MHz, or 16 percent extra bandwidth, ***for the same price***. That can make a big difference in the ability to offer new, revenue-generating services and expanded channel lineups.

Even operators who already are in the process of upgrading to 750 MHz can reap the tremendous benefits of switching to 870 MHz. With Scientific-Atlanta's new GainMaker™ broadband amplifier platform, an upgrade to 870 MHz is a simple drop-in solution – without the need for splicing or respacing.

The Scientific-Atlanta system is backward compatible, allowing the operator to keep their existing housing base. Maintenance and upgrade costs are reduced, and there is no labor premium for installing the 870 MHz system when upgrading existing Scientific-Atlanta amplifiers. Equipment and labor costs are also decreased because re-splicing or re-spacing of the network may not be required. This new generation of amplifiers includes several models to match any architecture requirements.

New Amplifiers Improve Reliability

As networks become more complex and customer expectations continue to grow, network reliability is more important than ever. Scientific-Atlanta has answered that challenge by adding new features to its amplifiers to ensure successful operation. For example, because the most common reason for system outage is loss of power, the new amplifiers feature a power supply located in the housing lid for quick replacement, should a failure occur. This also reduces heat in the amplifier, which often is the cause of maintenance problems.

The platform's system amplifier also operates with high gain and low noise at 870 MHz and contains a reverse amplifier in the chassis well for improved forward/reverse isolation. Hybrids are plug-ins instead of soldered for easy removal, and all accessories are accessible above the chassis cover.

The emergence of digital interactive services will place greater emphasis on bandwidth than ever before. By providing a simple and cost-effective upgrade to 870 MHz, Scientific-Atlanta is making it an easy choice to boost bandwidth and create a more robust, revenue-generating network.

For more information, visit the Scientific-Atlanta Web site at www.sciatl.com or call 770-903-5000.

If you are interested in viewing additional information or white papers from Scientific-Atlanta, Inc., please visit the Scientific-Atlanta Web site at www.sciatl.com.

Scientific Atlanta

APPENDIX B